Method and apparatus of particle transfer in multi-stage particle separators

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Title: METHOD AND APPARATUS OF PARTICLE TRANSFER IN MULTI-STAGE PARTICLE SEPARATORS
FIELD OF THE INVENTION
The present invention relates generally to the transfer and removal of particles separated in multi-stage separators such as may be used by vacuum cleaners. In one particular application, the invention relates to the multi-stage separation having upstream and downstream separation stages wherein the position at which the separated particles exit from the downstream separation stage is positioned above the position at which the separated particles exit the upstream separation stage.

BACKGROUND OF THE INVENTION
The use of multiple cyclones connected in parallel or series has long been known to be advantageous in the separation of particulate matter from a fluid stream. Typically, a relatively high speed fluid stream is introduced tangentially to a generally cylindrical orfrusto-conical first stage cyclone separator, wherein the dirty air stream is accelerated around the inner periphery of the first stage cyclone separator. Fluid exiting the first stage cyclone separator is fed to the inlet of a second stage cyclone separator wherein the described separation process is repeated. Typically, successive separators are configured to remove ever-smaller particles from the fluid stream, until a desired cleaning efficiency is achieved. Particulate matter disentrained from the fluid flow is typically collected at the bottom of each stage.

The advantages of multi-stage cyclonic separation are disclosed in U. S. Patent No. 3,425,192 to Davis. As shown in Figure 1, multi-stage separator 10 essentially comprises a large, lower first stage cyclone separator 12 connected in series with a plurality of smaller, parallel second stage cyclone separators 14 disposed over cyclone separator 12. A motor (not shown) draws air through a cleaning head and into a dirty air inlet 16 of the first stage cyclone separator12. From first stage cyclone separator 12, the air flows into second stage cyclone separators 14 and, from there, continues on through the vacuum motor to a clean air exhaust port (not shown). Particles separated from the fluid flow are deposited by first stage cyclone separator 12 into a primary collector 20, while particles separated from the fluid flow by second stage cyclone separators 14 are deposited into a secondary collector 22, vertically disposed over primary collector 20. When primary and/or secondary collectors 20 and 22 become laden with deposited particles, and must therefore be emptied, two distinct emptying steps are required to clear the collectors of their contents.

SUMMARY OF THE INVENTION
In accordance with the instant invention, there is provided a vacuum cleaner comprising a cleaner head having a dirty air inlet; and, a casing having a filtration member, the filtration member having an inlet in fluid flow communication with the dirty air inlet and an outlet in fluid flow communication with a source of suction, the filtration member comprising at least one upstream particle separator having an associated upstream particle collector and at least one downstream particle separator having an associated downstream particle collector, the particle collectors are configured such that the downstream particle collector is emptied by transferring its contents into the upstream particle collector.

In one embodiment, at least a portion of the upstream particle separator is removable from the casing and the downstream particle collector is emptied into the upstream particle collector when the when the portion of the upstream particle collector is removed from the casing.

In another embodiment, the vacuum cleaner further comprises a particle transfer member positioned between one of the particle separation members and its associated particle collector whereby particles separated by the said particle separation member are conveyed to said particle collector.

In another embodiment, at least a portion of the particle transfer member is angled downwardly whereby particles travel to said particle collector at least partially under the influence of gravity.

In another embodiment, the downstream particle separation member is chosen from the group of a cyclone, a Prandtl layer turbine and an electrostatic filter.

In another embodiment, the downstream particle collector is positioned in the upstream particle separation member.

In another embodiment, the downstream particle collector is pivotally mounted above the upstream particle collector.

In another embodiment, the downstream particle collector has side walls and a bottom that is mounted for movement between a closed position and an open position and the bottom moves to the open position as the upstream particle collector is prepared for emptying.

In another embodiment, the bottom is maintained in the closed position by interaction between the bottom and a member positioned on a portion of the vacuum cleaner that is not removed with the upstream particle collector.

In another embodiment, the downstream particle collector is disposed adjacent the upstream particle separation member.

In accordance with another aspect of the instant invention, there is provided a separator for separating entrained particles from a fluid flow, the separator comprising a first particle separation member; a reusable particle collector disposed beneath the particle separation member, the particle collector having a moveable member movably mounted between a closed position and an open position; and, a particle receiving chamber disposed beneath the particle collector, wherein when the moveable member moves from its closed position to its open position, particles collected in the particle collector are substantially transferred to the particle receiving chamber.

In accordance with another aspect of the instant invention, there is provided a separator comprising an inlet in fluid flow communication with a source of fluid having particles therein; a particle separation member; a first particle collector disposed below the particle separation member; and, a particle transfer member positioned between the particle separation member and the particle collector whereby particles separated by the particle separation member are conveyed to the particle collector.

In accordance with another aspect of the instant invention, there is provided a separator for separating entrained particles from a fluid flow, the separator comprising first separating means for separating particles from the fluid flow; second separating means for separating particles from the fluid flow; first particle collecting means for collecting particles separated from the fluid flow by the first separating means; second particle collecting means for collecting particles separated from the fluid flow by the second separating means; and, directing means for directing particles from the first particle separating means to the first particle collecting means.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made by way of example to the accompanying drawings.

The drawings show a preferred embodiment of the present invention, in which:
Figure 1 is a vertical cross section through a multi-stage cyclonic separator according to the prior art;
Figure 2 is a perspective view of a multi-stage separator according to the present invention;
Figure 3a is an exploded perspective view of the multi-stage separator of Figure 2;
Figure 3b is an exploded perspective view of an alternate embodiment of the multi-stage separator of Figure 2;
Figure 4 is a perspective view of the multi-stage separator of
Figure 2, with the second stage collector shown in a partially open position;
Figure 5 is a perspective view of a household vacuum cleaner according to the present invention;
Figure 6 is a perspective view of an alternate embodiment of a multi-stage separator having a particle transfer member according to the present invention;
Figure 7 is a perspective view of a further alternate embodiment of a multi-stage separator having a particle transfer member according to the present invention ;
Figure 8 is a perspective view of a further alternate embodiment of a household vacuum cleaner having a particle transfer member according to the present invention;
Figure 9 is a perspective view of a further alternate embodiment of the second stage particle collector according to the present invention; and,

Figure 10 is an enlarged side view of the second stage particle collector of Figure 9.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention relates to multi-stage particle separation systems wherein the particles separated in a second (or downstream) separation stage are transported to a position wherein they may be removed from the multi-stage particle separation systems together with the particles separated in a first (or upstream) separation stage. The improvements may be used in any multi-stage separation system wherein material separated by a second stage separation process is to be stored in a storage container which is to be periodically emptied. The downstream separation stage may use any separation technique, eg a cyclone separator, a Prandtl layer turbine, an electrostatic precipitator or the like, which produces separated particles that must be handled in such a way that they will not be re-entrained in fluid flowing through the downstream separation stage (eg, stored in a reusable container). Preferably, the downstream and the upstream separation stages use such separation techniques.

The preferred embodiment of the present invention is described in its use with a vacuum cleaner and in particular an upright vacuum cleaner. It will be appreciated that the improvements in multistage separation described herein may be used with canister vacuum cleaners, back pack vacuum cleaners, central vacuum cleaner systems as well as single and multi-stage separators of any sort, including industrial dust or particle collection systems wherein particles are to be removed from a fluid (i. e. a liquid and/or a gas).

An improved multi-stage separator according to the present invention is shown generally in the Figures at 30. Referring to Figure 2, separator 30 comprises a first stage cyclone 32 and a plurality of second stage cyclones 34. First stage cyclone 32 has a first stage collector 36 and second stage cyclones 34 have a second stage collector 38. First stage cyclone 32 and second stage cyclones 34 are housed within a housing 40 having a top 41, a lower portion comprising container 66 and an upper portion comprising second stage assembly 51. As shown in Figure 2, top 41 comprises a mesh screen that is positioned upstream of a motor driven fan. However, it will be appreciated that second stage assembly 51 may be open or it may be closed if it is provided with a fluid outlet. First stage cyclone 32 has an fluid inlet 42, fed by a fluid feed conduit 45, and a fluid outlet 46. Fluid outlet 46 feeds a transfer conduit 44 which is in fluid communication with a plurality of second stage cyclones 34 via a plurality of inlets 47. Second stage cyclones 34 each have a fluid outlet 49 positioned beneath mesh screen 41.

As shown in Figure 2, transfer conduit 44 extends above mesh screen 41 to engage a support member (not shown) to fix second stage cyclones 34 in position. The interior of conduit 44 is sealed to cause the air to enter second stage cyclones 43. Alternately, transfer conduit 44 may terminate at inlets47 and alternate support means may be provided to position second stage cyclones 34 in second stage assembly 51 (eg. by means of support members attached to the inner wall of second stage assembly 51).

While the first and second stages are connected in series, it will be appreciated that the improvements disclosed herein may be used in a system wherein the first and second stages are connected in parallel. It will also be appreciated that additional separation stages may be positioned upstream, downstream or both upstream and downstream from the first and second separation stages. It will further be appreciated that first stage cyclone 32 may comprise a plurality of cyclones and/or that the second stage may comprise only one second stage cyclone 34 (see for example Figure 7). The fluid may be propelled through separator 30 by any means known in the art. For example, a pump may be positioned upstream of separator 30 or, in the case of a vacuum cleaner, a source of suction (eg. a motor driven fan) may be positioned downstream from separator 30.

Beneath second stage cyclones 34 is a particle transfer member48 which slopes downwardly to second stage collector 38. Second stage collector 38 has side walls 50 and a bottom 52. Referring to Figure 3a, bottom 52 is separable from side walls 50.

In the embodiment wherein separator 30 is used in a vacuum cleaner (see, for example, Figure 5), a motor-driven fan draws particleladen fluid via a feed conduit into first stage inlet 42 via fluid feed conduit 45. The fluid flows cyclonically within a first stage cyclone 32 depositing particles in first stage collector 36 (which may be the bottom surface of container 66). The fluid exits first stage cyclone 32 via outlet 46 and is delivered by conduit 44 to the inlets 47 of second stage cyclones 34.

Cyclonic flow in second stage cyclones 34 further separates particles from the fluid flow, which particles fall on to particle transfer member 48 for transfer to second stage collector 38. The fluid flow then exits second stage cyclones 34 via outlets 49, and is expelled from separator 30. The separated particles travel

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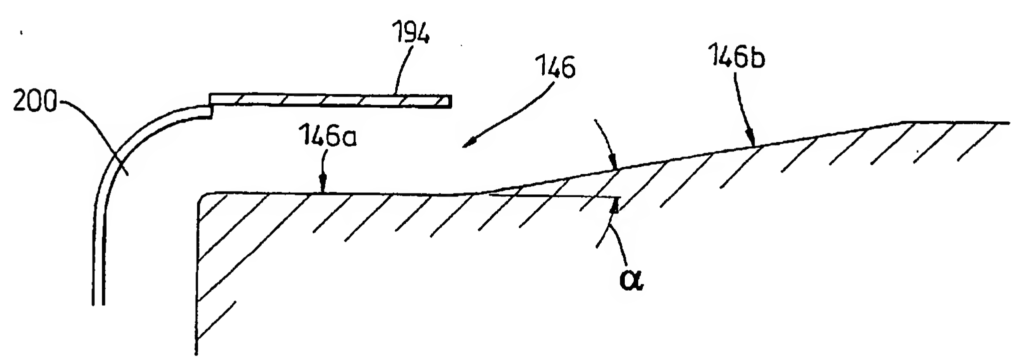
(54) Title: CYCLONIC SEPARATING APPARATUS



(57) Abstract: The invention provides cyclonic separating apparatus (100) comprising a plurality of cyclones (104) arranged in parallel with one another, each cyclone (104) having a tapering body (104a) and an inlet (146) constructed and arranged so as to create a helical flow within the tapering body (104a), wherein the inlet (146) for each cyclone (104) comprises a first portion (146a) which extends substantially perpendicular to the axis (148) of the respective cyclone (104) and a second portion (146b) which is inclined to the first portion (146a) in the direction of the cyclone (104).

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Cyclonic Separating Apparatus

The invention relates to cyclonic separating apparatus. Particularly, but not exclusively, the invention relates to cyclonic separating apparatus for use in vacuum cleaners.

Cyclonic separating apparatus is well known and has uses in a wide variety of applications. Over the last decade or so, the use of cyclonic separating apparatus to separate particles from an airflow in a vacuum cleaner has been developed and introduced to the market. Detailed descriptions of cyclonic separating apparatus for use in vacuum cleaners are given in, *inter alia*, US 3,425,192, US 4,373,228 and EP 0 042 723. From these and other prior art documents, it can be seen that it is known to provide two cyclone units in series so that the airflow passes sequentially through two cyclones. This allows the larger dirt and debris to be extracted from the airflow in the first cyclone, leaving the second cyclone to operate under optimum conditions and so effectively to remove very fine particles in an efficient manner. This type of arrangement has been found to be effective when dealing with airflows in which is entrained a variety of matter having a wide particle size distribution. Such is the case in vacuum cleaners.

In some cases, for example US 3,425,192 mentioned above, the second cyclone unit consists of a plurality of cyclones arranged in parallel. The incoming air is divided between the cyclones and this is achieved by allowing the inlets of the cyclones to communicate with a plenum chamber into which air exiting the first cyclone is admitted. Such an arrangement then requires each cyclone to have an individual inlet associated with it in order to ensure that the incoming air follows a helical path within each cyclone. If this is achieved simply by the provision of a helical vane inside the top of the cyclone, the incoming air can be uncontrolled and turbulent as it enters the cyclone. This can be detrimental to the operation of the cyclone.

It is an object of the present invention to provide cyclonic separating apparatus which is simple and economic to manufacture and/or to assemble in comparison to the prior art

and which provides a comparatively controlled entry for the incoming air. It is another object of the invention to provide cyclonic separating apparatus suitable for use in vacuum cleaners and capable of being manufactured at reduced cost compared to the prior art. It is a further object of the invention to provide cyclonic separating apparatus capable of mitigating the disadvantages of the prior art.

The invention provides cyclonic comprising a plurality of cyclones arranged in parallel with one another, each cyclone having a tapering body having an axis, and an inlet constructed and arranged so as to create a helical flow within the tapering body, wherein the inlet for each cyclone comprises a first portion which extends substantially perpendicular to the axis of the respective cyclone and a second portion which is inclined to the first portion in the direction of taper of the cyclone body.

This arrangement of the inlets to the cyclones maintains control of the incoming air as it enters the cyclone. The air is turned through 90° so as to cause it to flow perpendicular to the axis of the cyclone whilst it begins to follow a circular path. The air is then caused to move along the axis of the cyclone once the circular path has been commenced.

Preferably, the angle of inclination of the second portion to the first portion is between 5° and 20°, more preferably substantially 16°. This angle of inclination is beneficial with regard to the separation efficiency of the cyclone.

In a preferred embodiment, the first portion is closed on the side of the inlet facing the cyclone. More preferably, the first portion is closed by a plate located so as to cover a trough, the trough and the plate combining to delimit the first portion of the inlet. Such an arrangement is simple to manufacture and assemble.

Further preferred and advantageous features are set out in the subsidiary claims.

An embodiment of the invention will now be described with reference to the accompanying drawings, wherein:

Figures 1a and 1b are front and side views, respectively, of a vacuum cleaner incorporating cyclonic separating apparatus according to the invention;

Figures 2a, 2b and 2c are front, side and plan views, respectively, of a first embodiment of cyclonic separating apparatus forming part of the vacuum cleaner of Figures 1a and 1b;

Figures 3a and 3b are front and sectional side views, respectively, of the cyclonic separating apparatus of Figures 2a, 2b and 2c, Figure 3b being taken along the line III-III of Figure 3a;

Figures 4a, 4b and 4c are perspective, plan and sectional side views, respectively, of a cyclone portion of the cyclonic separating apparatus of Figures 2a, 2b and 2c, Figure 4c being taken along line IV-IV of Figure 4b;

Figures 5a and 5b are perspective views, taken from the top and bottom respectively, of an inlet support member forming part of the cyclonic separating apparatus of Figures 2a, 2b and 2c;

Figures 6a and 6b are plan and perspective views, respectively, of a vortex finder member forming part of the cyclonic separating apparatus of Figures 2a, 2b and 2c;

Figure 7 is a schematic sectional view taken along the length of an inlet forming part of the inlet support member of Figures 5a and 5b with the vortex finder member of Figures 6a and 6b located adjacent the inlet support member;

Figures 8a and 8b are plan and sectional views, respectively, of the inlet support member of Figures 5a and 5b and seven vortex finder members of the type shown in Figures 6a and 6b, Figure 8b being taken along the line VIII-VIII of Figure 8a; and

Figures 9a and 9b are views similar to those of Figures 8a and 8b but with the cyclone portion of Figures 4a, 4b and 4c positioned adjacent the inlet support member, Figure 9b being taken along the line IX-IX of Figure 9a.

Figures 1a and 1b show a domestic vacuum cleaner 10 incorporating cyclonic separating apparatus according to the present invention. The vacuum cleaner 10 comprises an upstanding body 12 at a lower end of which is located a motor casing 14. A cleaner head 16 is mounted in an articulated fashion on the motor casing 14. A suction inlet 18 is provided in the cleaner head 16 and wheels 20 are rotatably mounted on the motor casing 14 to allow the vacuum cleaner 10 to be manoeuvered over a surface to be cleaned.

Cyclonic separating apparatus 100 is mounted on the upstanding body 12 above the motor casing 14. The cyclonic separating apparatus 100 is seated on a generally horizontal surface formed by a filter cover 22. The filter cover 22 is located above the motor casing 14 and provides a cover for a post-motor filter (not shown). The cyclonic separating apparatus 100 is also secured to the upstanding body 12 by means of a clip 24 located at the top of the cyclonic separating apparatus 100. The upstanding body 12 incorporates upstream ducting (not shown) for carrying dirty air to an inlet of the cyclonic separating apparatus 100 and downstream ducting 26 for carrying cleaned air away from the cyclonic separating apparatus 100.

The upstanding body 12 further incorporates a hose and wand assembly 28 which may be retained in the configuration shown in the drawings so as to function as a handle for manoeuvering the vacuum cleaner 10 over a surface to be cleaned. Alternatively, the hose and wand assembly 28 may be released to allow the distal end 28a of the wand to be used in conjunction with a floor tool (not shown) to perform a cleaning function, eg

on stairs, upholstery, etc. The structure and operation of the hose and wand assembly 28 is not material to the present invention and will not be described any further here. The general structure and operation of the hose and wand assembly 28 illustrated in Figures 1a and 1b is similar to that described in US patent number Re 32,257 which is incorporated herein by reference. Also, several tools and accessories 30a, 30b, 30c, are releasably mounted on the upstanding body 12 for storage purposes between periods of use.

The precise details of the features of the vacuum cleaner 10 described above are not material to the present invention. The invention is concerned with the details of the cyclonic separation apparatus 100 forming part of the vacuum cleaner 10. In order for the cyclonic separation apparatus 100 to be brought into operation, the motor located in the motor casing 14 is activated so that air is drawn into the vacuum cleaner via either the suction inlet 18 or the distal end 28a of the hose and wand assembly 28. This dirty air (being air having dirt and dust entrained therein) is passed to the cyclonic separation apparatus 100 via the upstream ducting. After the air has passed through the cyclonic separation apparatus 100, it is ducted out of the cyclonic separating apparatus 100 and down the upstanding body 12 to the motor casing 14 via the downstream ducting 26. The cleaned air is used to cool the motor located in the motor casing 14 before being exhausted from the vacuum cleaner 10 via the filter cover 22.

This principle of operation of the vacuum cleaner 10 is known from the prior art. This invention is concerned with the cyclonic separation apparatus 100 which is illustrated in Figures 2a, 2b and 2c in isolation from the vacuum cleaner 10.

The cyclonic separation apparatus 100 illustrated in Figure 2 comprises an upstream cyclone unit 101 consisting of a single upstream cyclone 102 and a downstream cyclone unit 103 consisting of a plurality of downstream cyclones 104. The upstream cyclone 102 consists essentially of a cylindrical bin 106 having a closed base 108. The open upper end 110 of the cylindrical bin abuts against an inlet support member 112 which defines an upper end of the upstream cyclone 102 and will be described in more detail

below. An inlet port 114 is provided in the cylindrical bin 106 in order to allow dirty air to be introduced to the interior of the upstream cyclone 102. The inlet port 114 is shaped, positioned and configured to communicate with the upstream ducting which carries dirt-laden air from the cleaner head 16 to the cyclonic separating apparatus 100. A handle 116 and a catch 118 are provided on the cylindrical bin 106 and the inlet support member 112 respectively in order to provide means for releasing the cylindrical bin 106 from the inlet support member 112 when the cylindrical bin 106 requires to be emptied. A seal (not shown) can be provided between the cylindrical bin 106 and the inlet support member 112 if required.

The base 108 of the cylindrical bin can be hingedly connected to the remainder of the cylindrical bin in order to provide further access to the interior of the cylindrical bin 106 for emptying purposes if required. The embodiment illustrated herein will include a mechanism for allowing the base 108 to be hingedly opened in order to allow emptying, but the details of such a mechanism form the subject of a copending application and will not be described any further here.

Seven identical downstream cyclones 104 are provided in the downstream cyclone unit 103. The downstream cyclones 104 are equi-angularly spaced about the central longitudinal axis 150 of the downstream cyclone unit 103, which is coincident with the longitudinal axis of the upstream cyclone unit 101. The arrangement is illustrated in Figure 2c. Each downstream cyclone 104 is frusto-conical in shape with the larger end thereof located lowermost and the smaller end uppermost. Each downstream cyclone 104 has a longitudinal axis 148 (see Figure 3b) which is inclined slightly towards the longitudinal axis 150 of the downstream cyclone unit 103. This feature will be described in more detail below. Also, the outermost point of the lowermost end of each downstream cyclone 104 extends radially further from the longitudinal axis 150 of the downstream cyclone unit 103 than the wall of the cylindrical bin 106. The uppermost ends of the downstream cyclones 104 project inside an upper portion 120 which extends upwardly from the surfaces of the downstream cyclones 104. The upper portion 120 supports a handle 122 by means of which the entire cyclonic separation apparatus 100

can be transported. A catch 124 is provided on the handle 122 for the purposes of securing the cyclonic separation apparatus 100 to the upstanding body 12 at the upper end thereof. An outlet port 126 is provided in the inlet support member 112 for conducting cleaned air out of the cyclonic separating apparatus 100. The outlet port 126 is arranged and configured to co-operate with the downstream ducting 26 for carrying the cleaned air to the motor casing 14.

The upper portion 120 also carries an actuating lever 128 designed to activate a mechanism for opening the base 108 of the cylindrical bin 106 for emptying purposes as mentioned above.

The internal features of the cyclonic separating apparatus 100 will now be described with reference to Figure 3b. Figure 3a corresponds to Figure 2a and indicates the line III-III on which the section of Figure 3b is taken.

The internal features of the upstream cyclone 102 include an internal wall 132 extending the entire length thereof. The internal space defined by the internal wall 132 communicates with the interior of the upper portion 120 as will be described below. The purpose of the internal wall 132 is to define a collection space 134 for fine dust. Located inside the internal wall 132 and in the collection space 134 are components for allowing the base 108 to open when the actuating lever 128 is actuated. The precise details and operation of these components is immaterial to the present invention and will not be described any further here.

Mounted externally of the internal wall 132 are four equi-spaced baffles or fins 136 which project radially outwardly from the internal wall 132 towards the cylindrical bin 106. These baffles 136 assist with the deposition of large dirt and dust particles in the collection space 138 defined between the internal wall 132 and the cylindrical bin 106, adjacent the base 108. The particular features of the baffles 136 are described in more detail in WO 00/04816.

Located outwardly of the internal wall 132 in an upper portion of the upstream cyclone 102 is a shroud 140. The shroud extends upwardly from the baffles 136 and, together with the internal wall 132, defines an air passageway 142. The shroud 140 has a perforated portion 144 allowing air to pass from the interior of the upstream cyclone 102 to the air passageway 142. The air passageway 142 communicates with the inlet 146 of each of the downstream cyclones 104. Each inlet 146 is located in the inlet support member 112 and is arranged in the manner of a scroll so that air entering each downstream cyclone 104 is forced to follow a helical path within the respective downstream cyclone 104. The detail of the inlets 146 will be described in more detail below.

As previously mentioned, the longitudinal axis 148 of each downstream cyclone 104 is inclined towards the longitudinal axis 150 of the downstream cyclone unit 103. The upper end of each downstream cyclone 104 is closer to the longitudinal axis 150 than the lower end thereof. In this embodiment, the angle of inclination of the relevant axes 148 is substantially 7.5°.

The upper ends of the downstream cyclones 104 project inside the upper portion 120, as previously mentioned. The interior of the upper portion 120 defines a chamber 152 with which the upper ends of the downstream cyclones 104 communicate. The upper portion 120 and the surfaces of the downstream cyclones 104 together define an axially extending passageway or dust channel 154, located between the downstream cyclones 104, which communicates with the collection space 134 defined by the internal wall 132. It is thus possible for dirt and dust which exits the smaller ends of the downstream cyclones 104 to pass from the chamber 152 to the collection space 134 via the dust channel 154.

Figures 4a, 4b and 4c illustrate the arrangement of the downstream cyclones 104 in greater detail. In particular, this helps to illustrate the configuration of the dust channel 154. Figure 4b also helps to illustrate the fact that the side of each of the downstream cyclones 104 closest to the longitudinal axis of the downstream cyclone unit 103 lies

substantially parallel thereto. The downstream cyclones 104 have tapering bodies 104a which are arranged in a ring centered on the axis 150 of the downstream cyclone unit 103. A generally cylindrical wall 120a forming part of the upper portion 120 extends downwardly so as to meet the tapering bodies 104a. The downstream cyclones 104 and the cylindrical wall 120a are moulded integrally as a single piece 160, together with a collar 162 located adjacent the lower ends of the tapering bodies 104a and appropriate shapings 164 allowing the fixing of the single piece 160 to other parts of the cyclonic separating apparatus 100.

The inlet support member 112 is shown in detail in Figures 5a and 5b. The inlet support member 112 is moulded from a plastics material in a single piece and has a generally cylindrical wall 170 having a lower lip 172. The outlet port 126 is moulded into the cylindrical wall 170. Radially inwardly of the cylindrical wall 170 are second and third cylindrical walls 174, 176 between which are located baffle members 178. The baffle members 178, together with the second and third cylindrical walls 174, 176, define seven passageways 180 for carrying dirt- and dust-laden air to the inlets 146 of the downstream cyclones 104. These passageways 180 communicate with the air passageway 142 delimited by the shroud 140 and the internal wall 132. Between each pair of adjacent passageways 180 are blind recesses 182.

Extending between the upper portion of the cylindrical wall 170 and the upper portions of the baffle members 178 defining the passageways 180 is an upper portion of the inlet support member 112 incorporating seven identical mouldings 184 defining the inlets 146 of the downstream cyclones 104. Each moulding 184 is generally trough-shaped and follows a helical path about an aperture 186 extending through the upper portion of the inlet support member 112. Seven identical apertures 186 are provided and each aperture communicates with a chamber 188 defined by the first and second cylindrical walls 170, 174 and the mouldings 184. When the chamber 188 is closed by another part of the cyclonic separating apparatus, the apertures 186 are in communication with the outlet port 126. A locating peg 190 is provided adjacent each moulding 182. The purpose of the locating pegs 190 will be described below.

Figures 6a and 6b show a vortex finder member 192. The vortex finder member 192 comprises a vortex finder 156 which consists of an upstanding tubular collar of the same internal diameter as the aperture 186. The vortex finder functions as the outlet for air exiting the respective downstream cyclone 104. Mounted inside the vortex finder 156 is a centrebody 158 which helps to stabilize and straighten the airflow passing along the vortex finder 156. A plate 194 is provided at the base of the vortex finder 156. The shape of the plate 194 is such that, when the vortex finder member 192 is located adjacent one of the inlets 146, the plate 194 covers the inlet 146 from the point furthest downstream to an upstream point. A recess or aperture 196 is provided in the plate 194. The recess or aperture 198 is located and dimensioned so as to be able to receive the peg 190 located adjacent the respective inlet 146 so as to assist with the accurate location of the vortex finder member 192. The vortex finder member 192 is fixed in position by welding around the base of the vortex finder 156. No fixing need be provided between the outer edge of the plate 194 and the inlet 146.

The shape of the inlets 146 is described in more detail with reference to Figure 7 which is a schematic view along the length of one of the inlets 146 assuming that the inlet followed a straight path instead of a helical one. As can be seen, the passageway 180 terminates in a right-angled bend 200 whose walls are moulded integrally with the inlet support member 112. The inlet 146, formed by a trough moulded into the inlet support member 112, has a first portion 146a which extends substantially perpendicularly to the axis 148 of the downstream cyclone to which the inlet 146 relates (see Figure 9b). The inlet 146 has a second portion 146b which is inclined to the first portion 146a in the direction of taper of the downstream cyclone 104 at a slight angle α. The size of the angle α can vary from as little as 5° to as much as 20 °, an angle of approximately 16° being preferred. When the vortex finder member 192 is placed in position adjacent the inlet 146, the plate 194 covers the first portion 146a of the inlet 146 but not the second portion 146b. Hence the portion 146a of the inlet 146 which lies substantially parallel to the axis 148 of the respective cyclone 104. The second portion 146b, which directs the incoming air along the axis 148, is open on one side, specifically the side facing the

cyclone 104. This arrangement controls the incoming air as it begins to establish a helical flow pattern and then allows the airflow to follow a free vortex path as it passes along the axis. The channel or trough which forms the inlet 146 is contoured on the lower side thereof to provide a smooth surface across which the incoming air can pass so as to reduce friction losses.

Figures 8a and 8b show the inlet support member 112 with seven vortex finder members 192 placed in position adjacent the respective inlets 146. The section shown in Figure 8b is taken along the line VIII-VIII. As can be seen from Figure 8a, the axes of the vortex finders 156 are inclined slightly towards the central longitudinal axis of the inlet support member 112 so as to coincide with the axes of the downstream cyclones 104. Hence, the directions of the first portions 146a of the inlets 146 do not lie precisely horizontally, but are inclined downwardly towards the lower lip 172 of the cyclindrical wall 170.

Figures 9a and 9b are views similar to those shown in Figures 8a and 8b but with the integral piece 160 incorporating the downstream cyclones 104 attached to the inlet support member 112 as well. As can be seen, one of the tapering bodies 104a is fitted over each of the inlets 146 so that the inlet 146 opens into the respective tapering body 104a. The inlet support member 112 includes a circular lip 202 around each of the mouldings 184 which define the inlets 146. The lower edge of each tapering body 104a locates inside one of the lips 202 and is fixed therein by any suitable means such as adhesive, welding, interference fit, screws, etc. If adhesives are used, the outer edge of the plate 194 can be fixed in position simultaneously with the fixing of the cyclones 104. The vortex finder 156 then projects into the tapering body 104a and communicates therewith so as to allow air to exit from the cyclone 104 into the chamber 188. The inner edge of the collar 162 abuts against the top of the third cylindrical wall176 when the cyclone portion 160 is located adjacent the inlet support member 112. A seal is formed between these two members. The third cylindrical wall 176 forms a further dust channel 204 which forms an extension of the dust channel 154.

As will be understood from the preceding description, the inlet support member 112 is located on top of the upstream cyclone 102. When the inlet support member 112 is placed in position, the lower lip 172 of the first cylindrical wall 170 comes into sealing contact with an annular plate 206 which is located on top of the upstream cyclone 102 and closes the top thereof radially outwardly of the shroud 140. Simultaneously, the second cylindrical wall 174 is brought into sealing engagement with an upper portion of the shroud 140 and the third cylindrical wall is brought into sealing engagement with the upper end of the internal wall 132. Thus the further dust channel 204 is brought into sealed communication with the dust collector 134 and the inlets 146 are brought into sealed communication with the air passageway 142.

The mode of operation of the apparatus described above is as follows. Dirty air (being air in which dirt and dust is entrained) enters the cyclonic separating apparatus 100 via the inlet port 114 . The arrangement of the inlet port 114 is essentially tangential to the wall of the cylindrical bin 106 which causes the incoming air to follow a helical path around the inside of the cylindrical bin 106. Larger dirt and dust particles, along with fluff and other large debris, are deposited in the collection space 138 adjacent the base 108 by virtue of the effect of centrifugal forces acting on the particles, as is well known.. Partially cleaned air travels inwardly and upwardly away from the base 108, exiting the upstream cyclone 102 via the perforated portion 144 of the shroud 140. The partially-cleaned air then moves along the air passageway 142 in which it is divided into seven portions. Each portion enters one of the downstream cyclones 104 via the respective inlet 146. As has been mentioned above, each inlet 146 is a scroll inlet which forces the incoming air to follow a helical path inside the downstream cyclone 104. The tapering shape of the downstream cyclone 104 causes further, intense cyclonic separation to take place inside the downstream cyclone 104 so that very fine dirt and dust particles are separated from the main airflow. The dirt and dust particles exit the uppermost end of the downstream cyclone 104 whilst the cleaned air returns to the lower end of the downstream cyclone 104 along the axis 148 thereof and exits via the vortex finder 156. The cleaned air passes from the vortex finder 156 into the annular chamber 188 and from there to the outlet port 126. Meanwhile, the dirt and dust which has been

separated from the airflow in the downstream cyclone 104 falls from the chamber 152 through the dust channel 154 to the collection space 134. It is prevented from passing to the open uppermost end of the adjacent cyclones 104 by the fins 153.

When it is desired to empty the cyclonic separating apparatus 100, the base 108 can be hingedly released from the sidewall of the cylindrical bin 106 so that the dirt and debris collected in collection spaces 134 and 138 can be allowed to drop into an appropriate receptacle. As previously explained, the detailed operation of the emptying mechanism does not form part of the present invention and will not be described any further here.

The invention is not limited to the precise details of the embodiments described above. It must be stressed that the features of the vacuum cleaner in which the cyclonic cleaning apparatus is to be used are immaterial to the invention. Indeed, it is envisaged that cyclonic separating apparatus of the type described above can be put to use in other areas where good separation efficiencies combined with low pressure drops are required. It will be appreciated that, if desired, either or both of the upstream and downstream cyclone units can be made up of either a single cyclone or a plurality of cyclones arranged in parallel. Furthermore, there is no particular need for the apparatus to be arranged so that the axes of the cyclone units are vertical and the axes may indeed be inclined to the vertical or even horizontal if desired. The fact that centrifugal separation is not greatly affected by gravity makes this possible as long as the collecting areas of the cyclone units are arranged to collect the debris without interference to the airflow paths necessary to effect separation. In a further variation to the embodiment described in detail above, the downstream cyclones illustrated above may be arranged so that their respective axes are arranged parallel to one another instead of being inclined towards the axis of the downstream cyclone unit as shown in the drawings. Other variations and modifications will be apparent to a skilled reader.

Claims:

1. Cyclonic separating apparatus comprising a plurality of cyclones arranged in parallel with one another, each cyclone having a tapering body having an axis, and an inlet constructed and arranged so as to create a helical flow within the tapering body, wherein the inlet for each cyclone comprises a first portion which extends substantially perpendicular to the axis of the respective cyclone and a second portion which is inclined to the first portion in the direction of taper of the cyclone body.

2. Cyclonic separating apparatus as claimed in claim 1, wherein the second portion is inclined to the first portion at an angle of between 5° and 20°.

3. Cyclonic separating apparatus as claimed in claim 2, wherein the second portion is inclined to the first portion at an angle of substantially 16°.

4. Cyclonic separating apparatus as claimed in any one of the preceding claims, wherein the first portion is closed on the side thereof facing the cyclone.

5. Cyclonic separating apparatus as claimed in claim 4, wherein the first portion is closed by a plate located so as to cover a trough, the trough and the plate combining to delimit the first portion of the inlet.

6. Cyclonic separating apparatus as claimed in any one of the preceding claims, wherein the second portion of the inlet is open to the cyclone.

7. Cyclonic separating apparatus as claimed in any one of the preceding claims, wherein the inlet for each cyclone is formed in an inlet support member by moulding.

8. Cyclonic separating apparatus as claimed in claim 7, wherein the inlets for all of the cyclones are formed in the inlet support member.

9. Cyclonic separating apparatus as claimed in claim 7 or 8, wherein the inlet support moulding includes a right-angled bend immediately upstream of and communicating with the first portion of each inlet.

10. Cyclonic separating apparatus as claimed in any one of the preceding claims, wherein seven cyclones are provided.

11. Cyclonic separating apparatus as claimed in any one of the preceding claims, wherein a further cyclone is provided upstream of the plurality of cyclones.

12. Cyclonic separating apparatus substantially as hereinbefore described with reference to the accompanying drawings.

13. A vacuum cleaner incorporating cyclonic separating apparatus according to any one of the preceding claims.

14. A vacuum cleaner substantially as hereinbefore described with reference to the accompanying drawings.

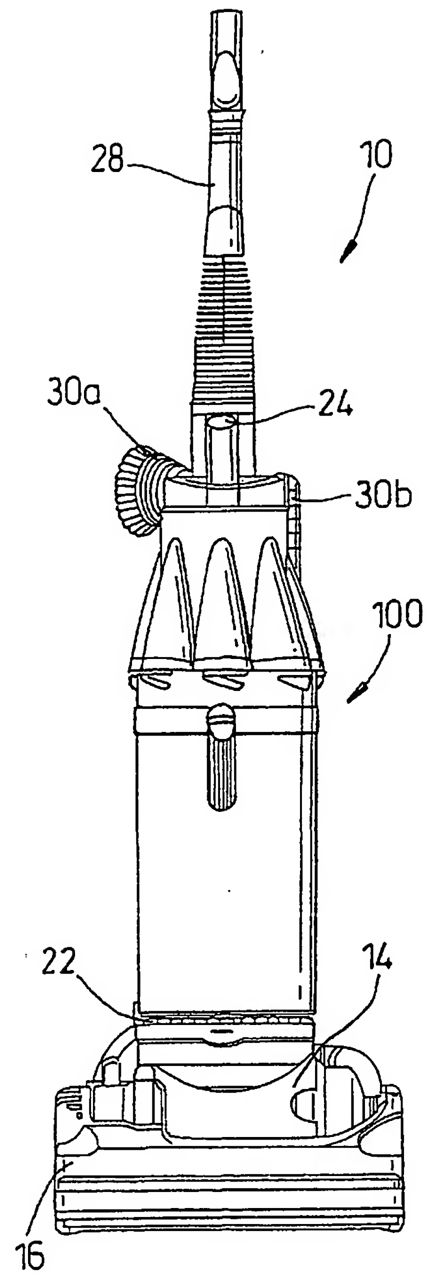
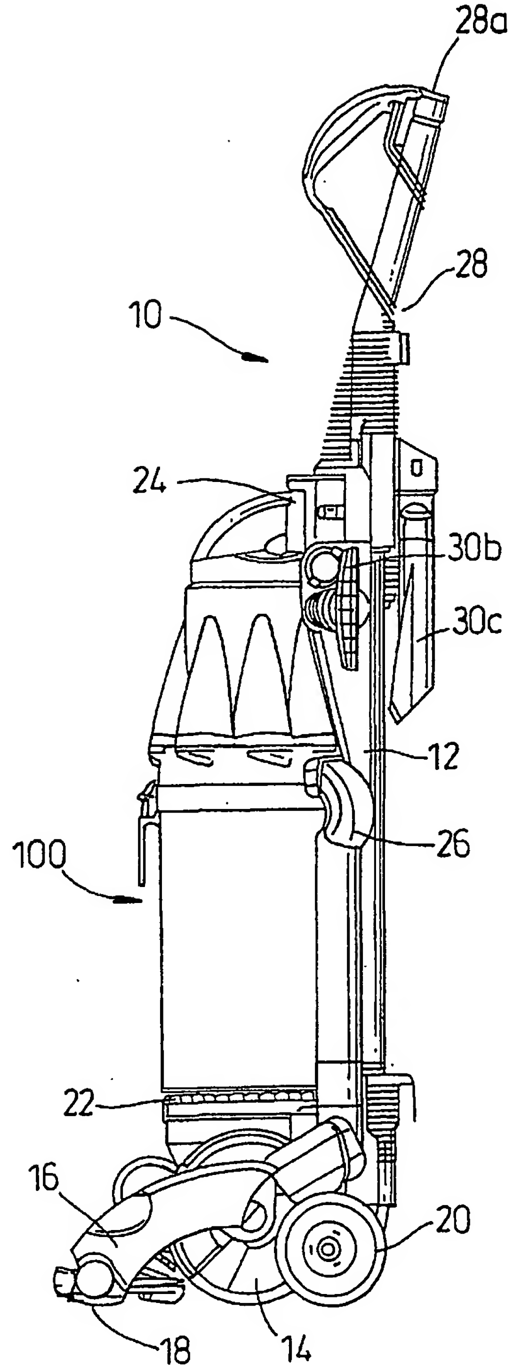

28
10
30a
24
30b
100
22
14
16

Fig. 1a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30c
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18
14

Fig. 1b

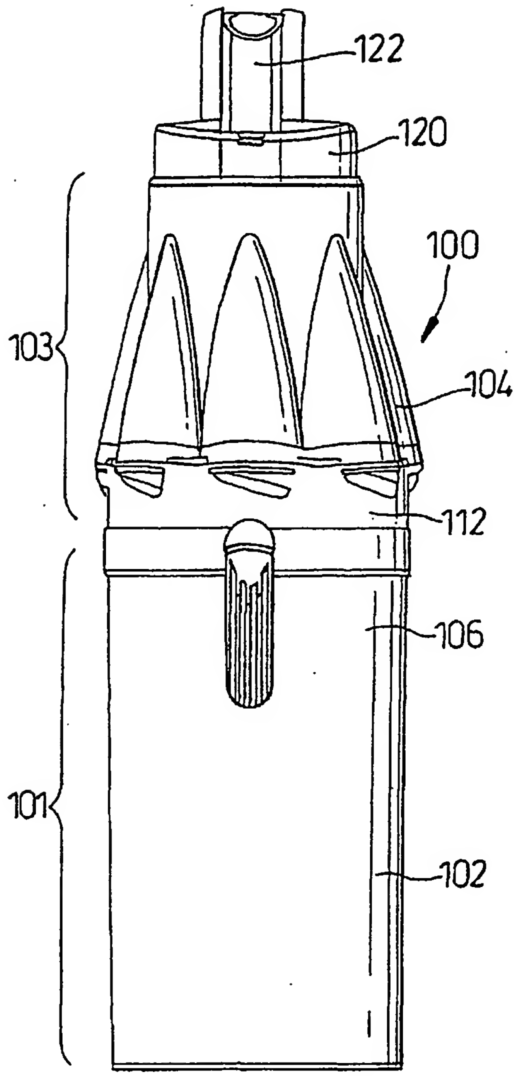


Fig. 2a

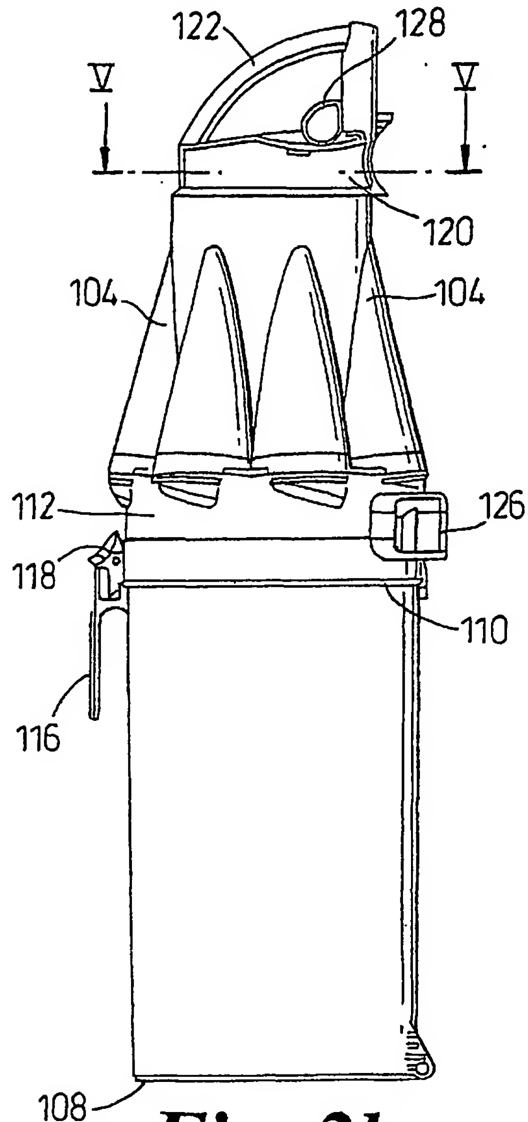


Fig. 2b

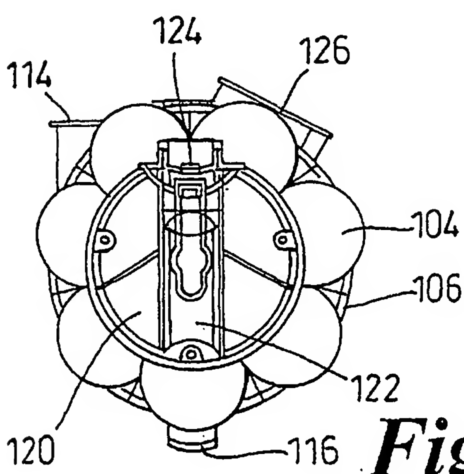
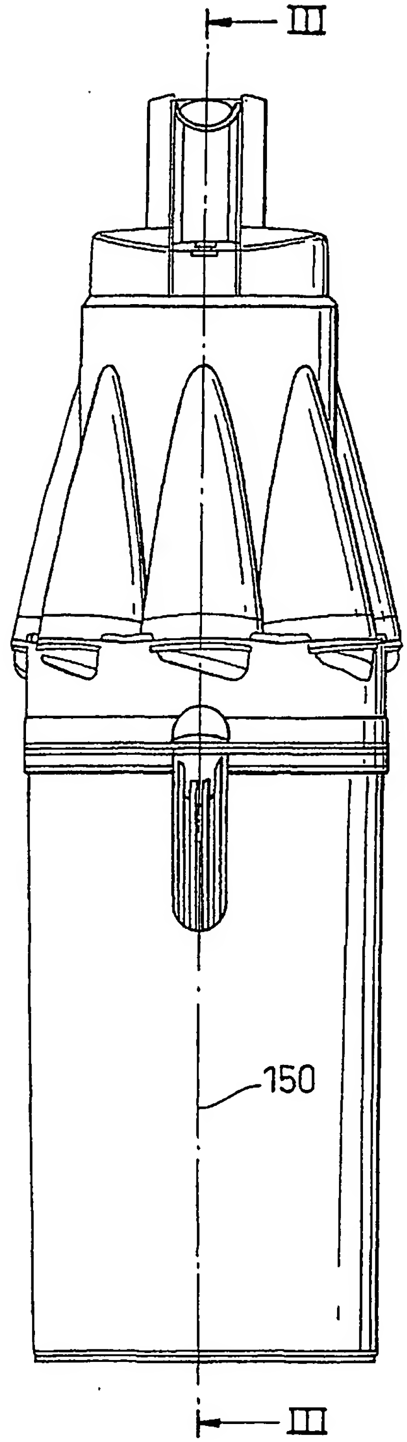


Fig. 2c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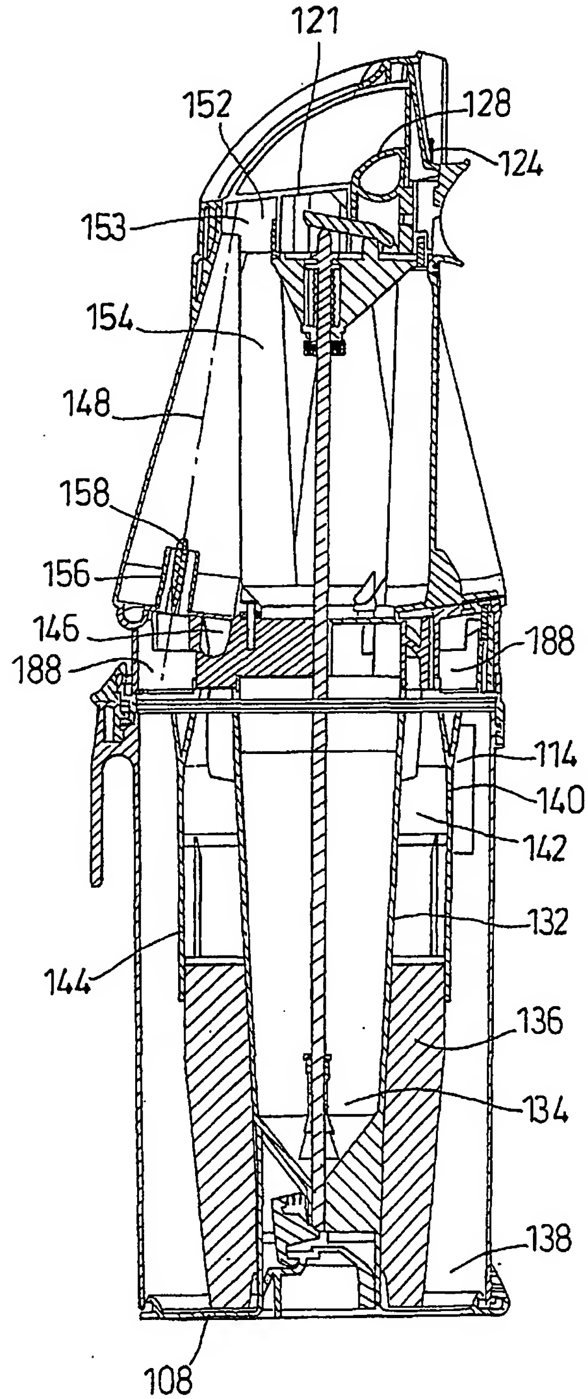
III

Fig. 3a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152
128
124
153
154
148
158
156
146
188
188
114
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134
138
108

Fig. 3b

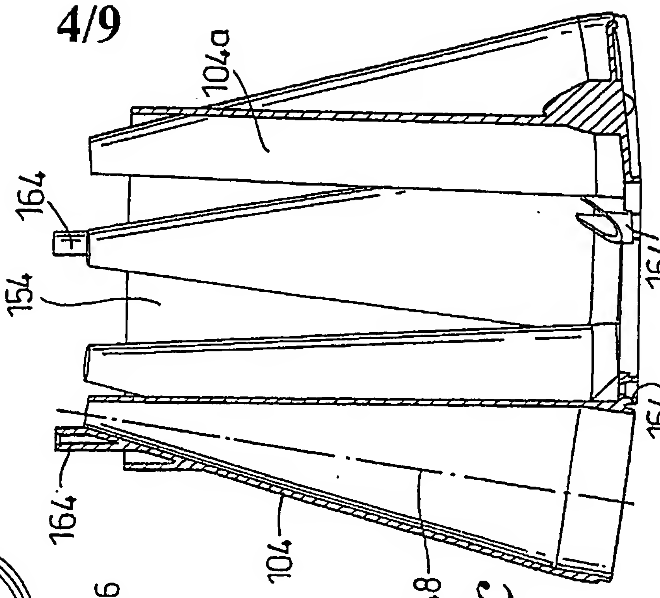


Fig. 4c

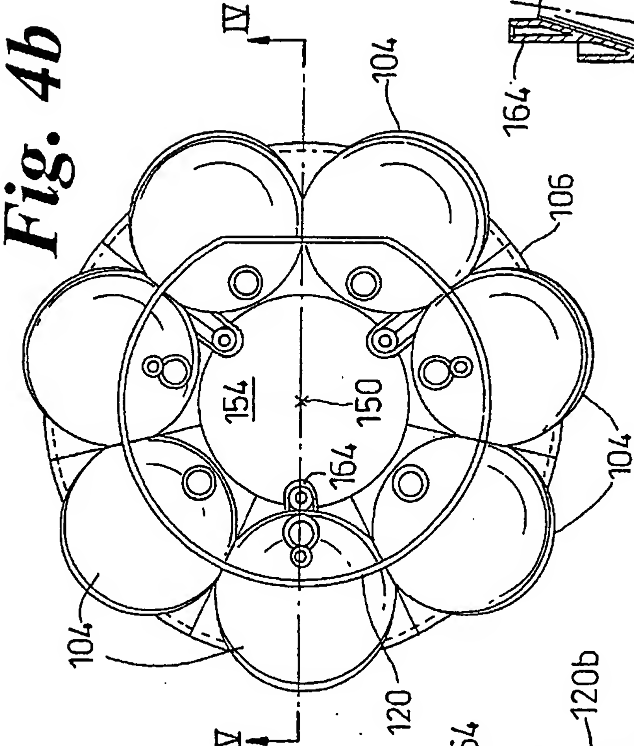


Fig. 4b

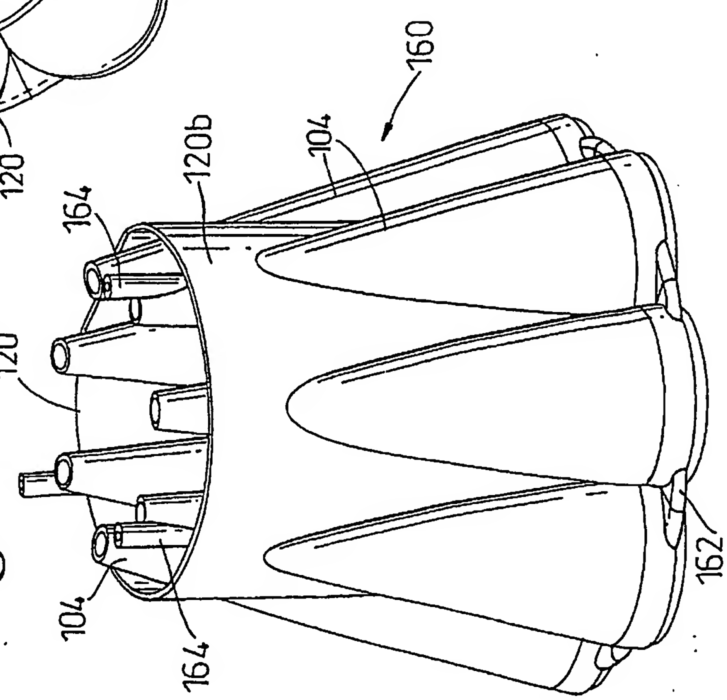
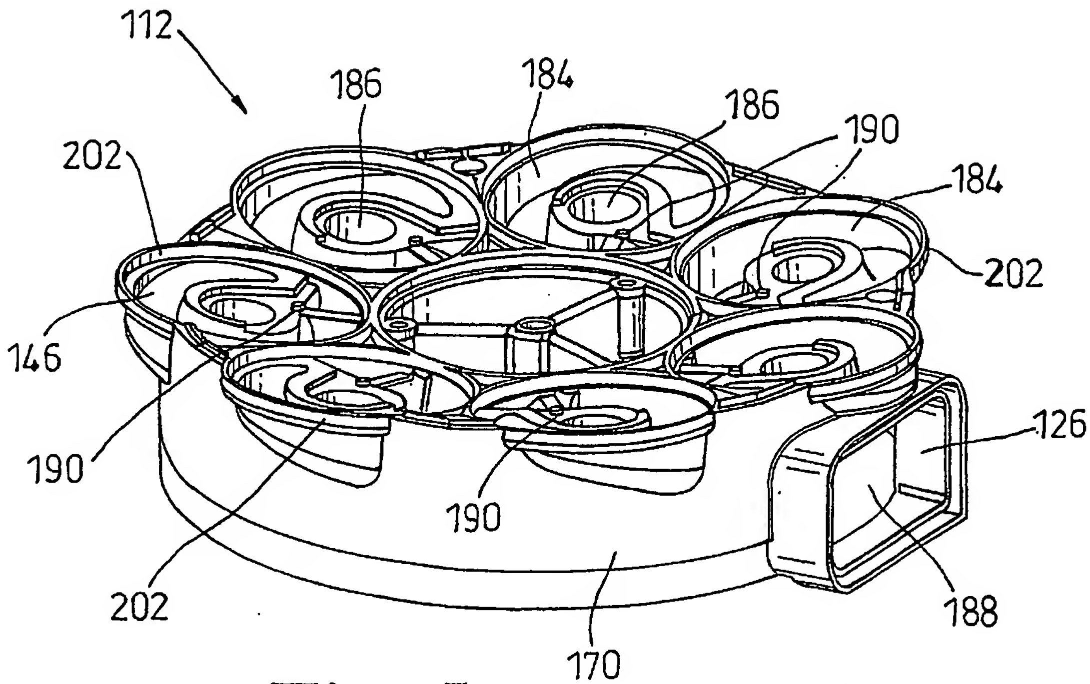


Fig. 4a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146
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126
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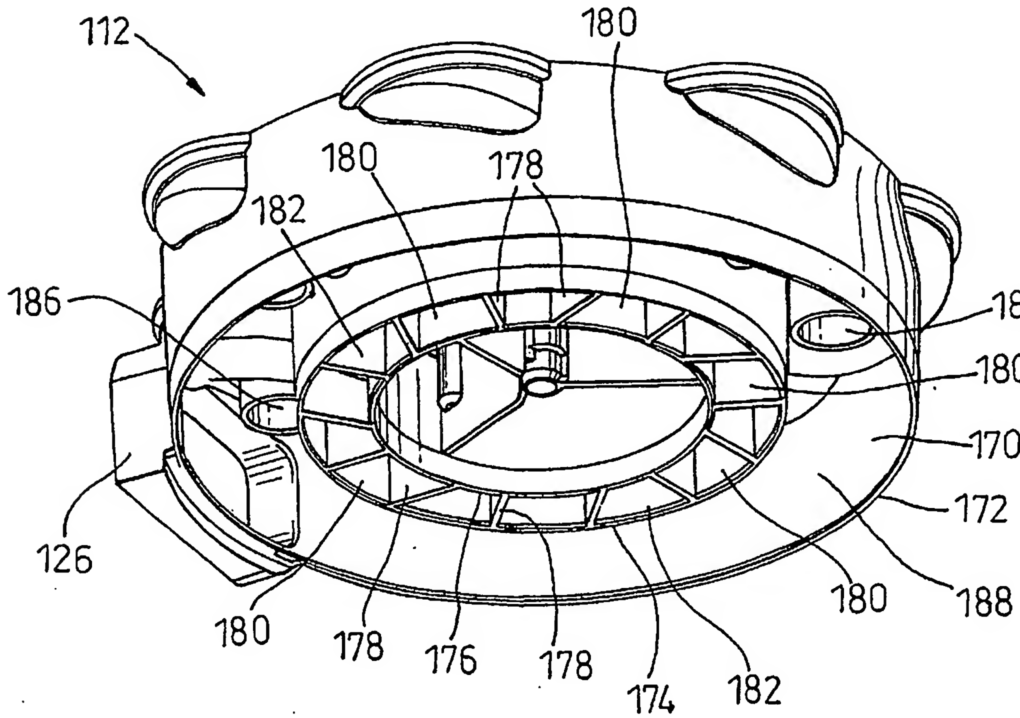
202
188
170

Fig. 5a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174
182

Fig. 5b

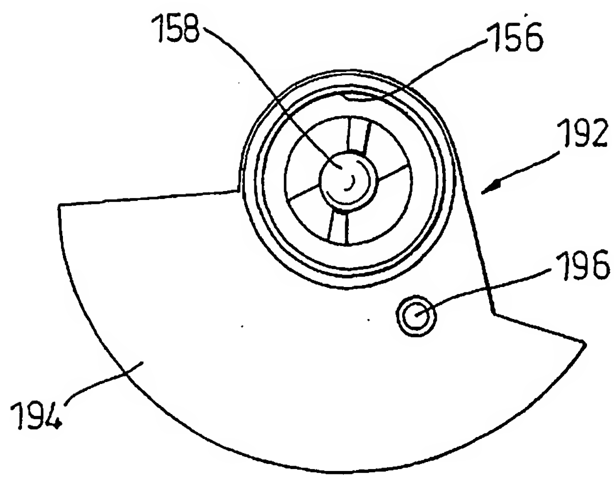


Fig. 6a

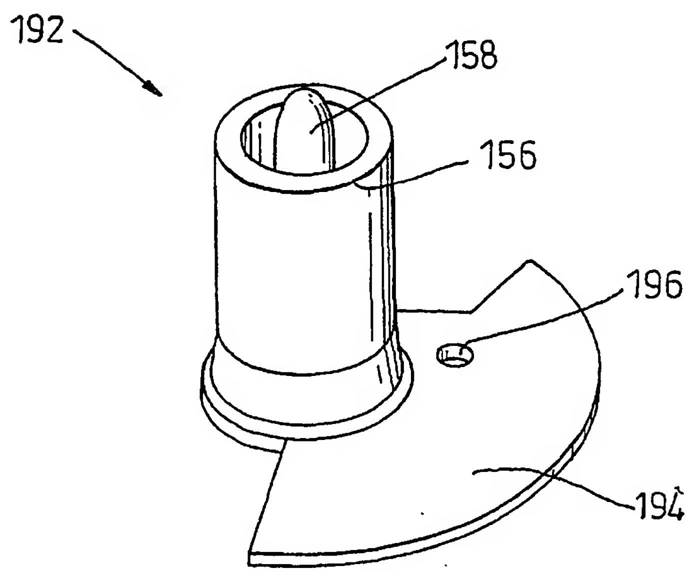


Fig. 6b

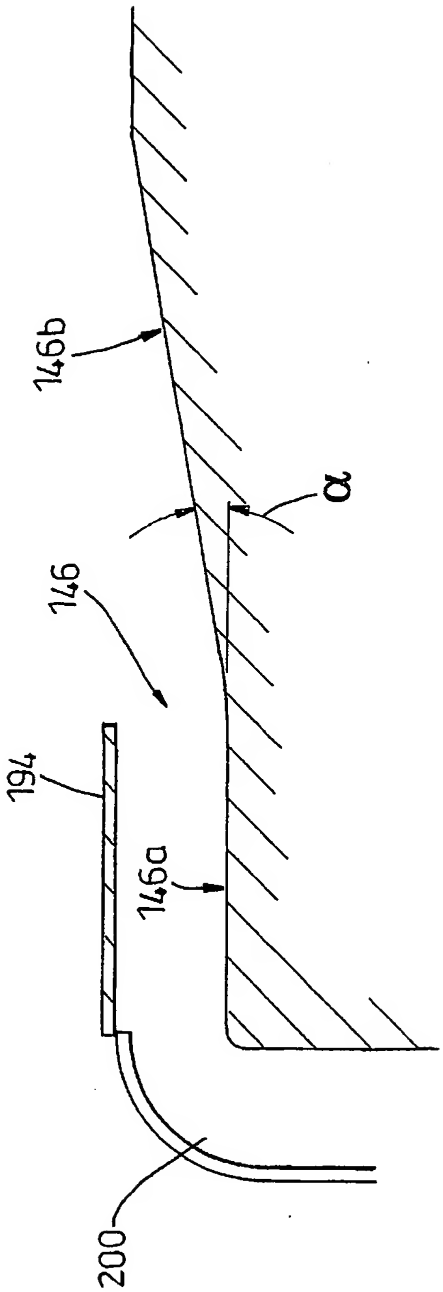
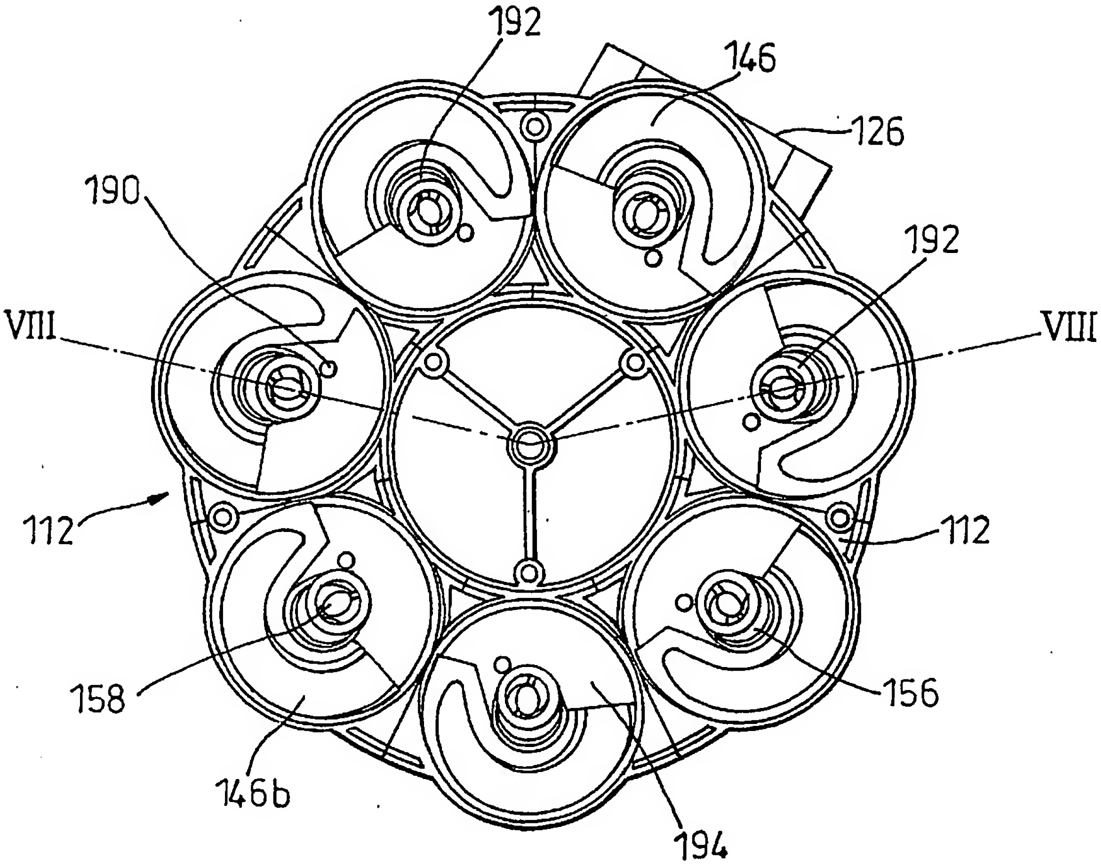


Fig. 7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146
126
190
192
VIII
VIII
112
112
158
156
146b
194

Fig. 8a

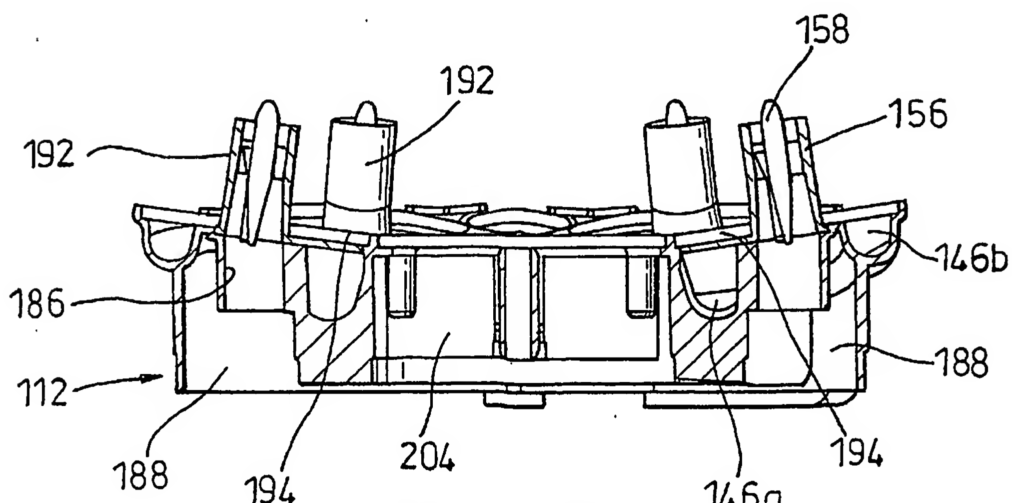

158
192
156
192
146b
186
188
112
188
194
204
146a
194

Fig. 8b

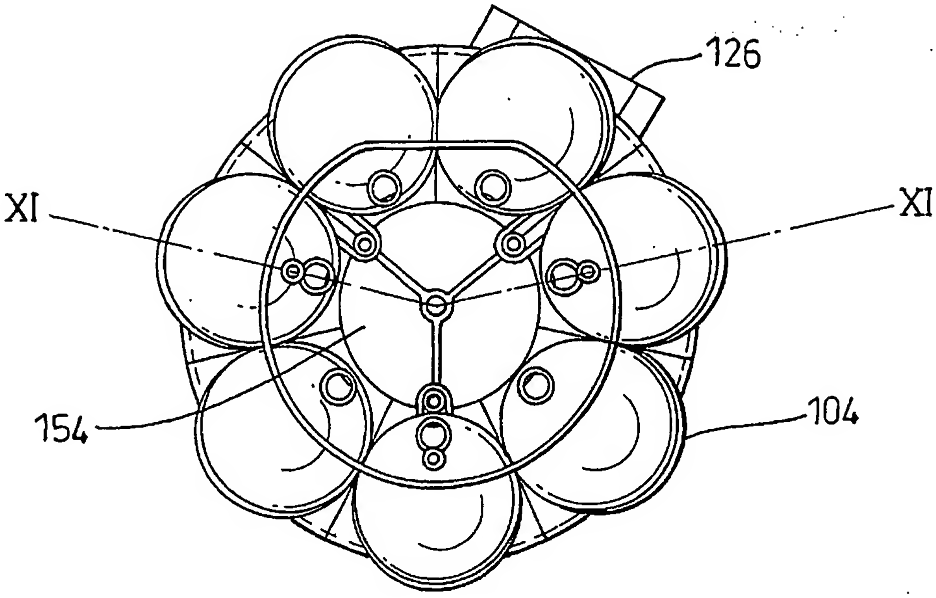
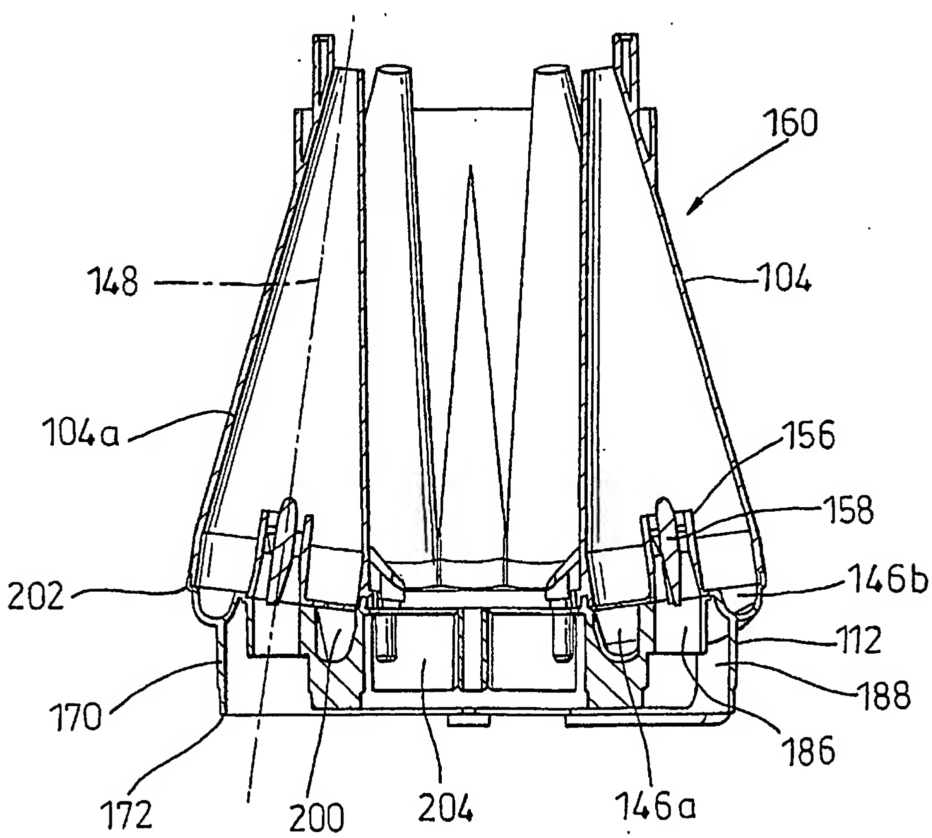

126
XI
XI
154
104

Fig. 9a


160
148
104
104a
156
158
202
146b
112
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186
172
200
204
146a

Fig. 9b

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/00333

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A47L9/16 B01D45/16 B04C5/28 B04C5/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A47L B01D B04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	EP 0 042 723 A (ROTORK APPLIANCES LTD) 30 December 1981 (1981-12-30) cited in the application abstract figure 2	1
A	DE 12 74 857 B (BAYER AG) 8 August 1968 (1968-08-08) column 2, line 21 - line 23 figures 1,2	1

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 May 2002	29/05/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cabral Matos, A

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 1 020 229 A (ABB ALSTOM POWER COMBUSTION) 19 July 2000 (2000-07-19) figure 7	1
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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PCT/GB 02/00333

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